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Effects of long-term artificial acid rain on species range and diversity of soil nematodes

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Abstract

Five years acidification of the soil due to artificial sulphuric acid rain did not significantly affect total number of nematodes. It did, however, change the community structure. In soil treated with sulphuric acid the number of nematode genera and species diversity were lower than in the untreated soil. Sulphuric acid introduced into the soil eliminated predatory and omnivorous species of nematodes.

Keywords: Artificial acid rain, nematode community, species diversity, sulphuric acid.

Effets des pluies acides artificielles de longue durée sur la diversité des nématodes du sol.

Résumé

L'influence de pluies acides sur l'abondance et la diversité spécifique des communautés des nématodes a été étudiée dans un champ expérimental divisé en parcelles de 2,25 m^2 chacune. Six parcelles ont été arrosées d'eau deux fois par semaine (témoin). Six autres parcelles ont été arrosées de solution d'acide sulfurique à pH 2,5 deux fois par semaine (acidification faible) et les six dernières parcelles ont été traitées de la même manière et, de plus, elles ont été arrosées de solution d'acide sulfurique à pH 1,5 une fois par trimestre (acidification forte). Les premiers échantillons du sol ont été prélevés après cinq années d'expérimentation. Les prélèvements ont été effectués pendant deux années, en mai et en octobre. Après cinq années d'acidification, le pH du sol a baissé significativement en comparaison avec le témoin : de 1,1 à 1,7 unités dans le cas de l'acidification faible, et de 2,2 à 2,3 unités dans le cas de l'acidification forte.

L'acidification n'a pas changé significativement l'abondance des nématodes, mais elle a cependant influencé la structure de leur communauté. Dans les parcelles à acidification forte, omnivores et prédateurs étaient éliminés. Le nombre de genres et l'indice de diversité spécifique de Shannon ont été significativement plus faibles sous forte acidification que sous faible acidification ou dans le témoin.

Mots-clés : Pluie acide artificielle, communauté de nématodes, diversité spécifique, acide sulfurique.

INTRODUCTION

The effect of acid precipitation on soil environment is drawing the attention of many scientists. In the last years acid rain has become the common environmental pollutant in many developed countries and large areas of Europe and North America are threatened with acid deposition. One of the consequences of acid rain is a decrease of soil pH. Several studies have shown that changes in soil acidity influence the community structure of Acari, Collembola and Enchytraeidae (Baath, *et al.*, 1980, Hagvar, 1984, 1986, Hagvar and Amundsen, 1981, Huhta *et al.*, 1986, Persson *et al.*, 1989). According to these authors some of these invertebrate species were sensitive to low pH and decreased in acidified soil, others, which were resistant, developed well and dominated in communities. Stachurska-Hagen (1980) studying effect of acid rain on Protozoa noticed certain changes in relative abundance of the most common species

of Testacea. Changes in soil acidity affected also nematode communities. Ruess and Funke (1992) and Dmowska (in press) observed negative reactions of saprobiotic nematodes to decreasing soil pH due to sulphuric acid. The same tendency was noticed by other authors who in contrast increased soil pH applying lime and ash (Hyvonen and Huhta, 1989), or potassium hydroxide Heungens (1981).

The aim of this study was to investigate five years effects of acid rain on soil nematodes. Total number, number of genera, species range and species diversity were analyzed.

SITE

The study was performed in the experimental field sown with grass (Lolium) in Dziekanów Leśny near Warsaw. In respect to plant cover this field is comparable to grassland. The soil of the field composed of light loamy sand was deposited on loose sand or weak loamy sand as its mother rock. The experimental field was divided into 60 plots (2.25 m^2 each plot). The experiment was carried out in several variants of acidification each comprising 6 plots. The individual microplots were included in different variants on a random basis. For nematological study the soil samples were taken from the plots belonging to the following variants:

– Variant 0 (V0) - the control: The soil was treated with tap water twice a week - 10 l. per plot.

– Variant 1 (V1) - weak acidification: The soil was treated with sulphuric acid solution twice a week (0.05 N, pH 2.5) - 10 l. per plot.

– Variant 2 (V2) - strong acidification: The soil was treated in the same way as in V1; in addition with strong sulphuric acid solution (0.5 N, pH 1.5) every three months.

The first soil samples for studying nematodes were taken in the fifth year of simulation of artificial acid rain in October 1988, the next samples were collected in May 1989, October 1989 and May 1990. The samples were taken with the use of 20 mm soil corer from 0-20 cm depth.

From the plots belonging to each variant 36 cores were taken - 6 cores per 1 plot.

METHODS

After mixing the soil well, 500 g from each variant was processed. Nematodes were extracted in Seinhorst's apparatus (Seinhorst, 1962). After the extraction, nematodes were counted and identified; larvae to genus, adults to species level.

pH of every soil sample was determined in triplicate using mixtures of soil and distilled water (1:1).

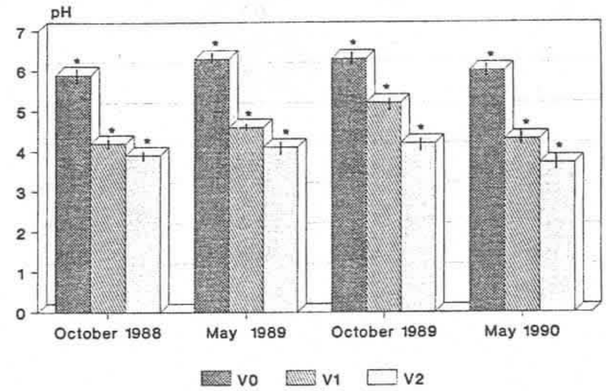

Figure 1. – $pH_{(H_2O)}$ of soil in three variants. Means of triplicate assays.
V0 – control, V1 – weak acidification, V2 – strong acidification;
* – with p = 0.05 significantly different from the control in the same year and season.

For statistical evaluation of differences between total number of nematodes in three treatments Friedman two ways analysis by ranks was applied. (Siegel, 1956).

Mann-Whitney U-test was used to test the significance of differences in value of pH and number of genera in three variants of the experiment. (Siegel, 1956). (Level of significance = 0.05).

The degree of diversity of nematode communities was estimated by Shannon-Weaver diversity index. Significance between the diversity in three variants was tested with the t-test (Pilou, 1974).

RESULTS

pH of soil

Changes in pH during two years in the control and two variants of acidification are illustrated in *figure* 1. The obtained data indicate that sulphuric acid solution used in the experiment as simulated acid rain caused an increase in the acidity of the soil. In two years of the experiment some fluctuations of pH in every variant were observed. Nevertheless, the acidification of soil in V2 was always greater than in V1. The differences between pH in V0 and V1 (1.1 - 1.7 units), were significant (p = 0.05), between V0 and V2 (2 - 2.3 units) were also significant (p = 0.05).

Total number of nematodes

The data presented in *table* 1 and *table* 2 indicate that in the spring the highest number of nematodes was in V0 (control) and decreased in soil treated with sulphuric acid. The smallest number of nematodes was observed in V2 (strong acidification). In the autumn samples there was no influence at all of acid rain on the number of nematodes. The most numerous

Table 1. – Taxonomic composition of nematode communities in spring in the control (V0) and two variants of acidification (V1 and V2). Number of individuals (10^{-3} per m^2) (in normal type). Percentage of taxa in the community (in italics).

Taxa	1989			1990		
	Variants					
	V0	V1	V2	V0	V1	V2
Acrobeles ciliatus	15.3			17.0		
Linstow, 1877	*2.0*			*2.1*		
Acrobeloides bütschlii	7.6			8.5	17.0	12.7
de Man, 1884	*1.0*			*1.0*	*2.6*	*3.3*
A. enoplus	7.6			42.5		8.5
Steiner, 1838	*1.0*			*5.2*		*2.2*
A. minor			2.5		59.6	
Thorne, 1925, Thorne, 1937			*0.8*		*9.2*	
Alaimus sp.	15.3	5.5	2.5	4.2		
	2.0	*0.8*	*0.8*	*0.5*		
A. parvus	16.6	31.9		4.2		
Thorne, 1939	*2.2*	*4.7*		*0.5*		
Aphelenchoides sp.	5.3	22.1	23.0	51.1		38.2
	0.7	*3.2*	*6.7*	*6.3*		*9.9*
A. bicaudatus	5.9			8.5		
Imamura, 1931	*0.8*			*1.0*		
A. composticola			5.9			
Franklin, 1957			*1.7*			
A. dubius	5.9			8.5	34.0	38.3
Wasilewska, 1969	*0.8*			*1.0*	*5.3*	*9.9*
A. hoeliophilus	5.9			8.5		
de Man, 1880, Goodey, 1933	*0.8*			*1.0*		
A. parietinus					59.5	10.6
Bastian, 1865					*9.2*	*2.8*
A. pusilus						17.0
Thorne, 1929, Filipjev, 1934						*4.4*
A. saprophilus	11.9	11.0	11.9	8.5		167.8
Franklin, 1957	*1.6*	*1.6*	*3.5*	*1.0*		*43.6*
A. subparietinus	15.3		5.1	17.0		30.0
Sanval, 1961	*2.0*		*1.5*	*2.1*		*7.8*
A. subtenuis	45.9		2.5	8.5	8.5	
Cobb, 1926	*6.1*		*0.8*	*1.0*	*1.3*	
Aphelenchus avenae	5.1	5.5	10.2	42.5	17.0	
Bastian, 1865	*0.7*	*0.8*	*3.0*	*5.2*	*2.6*	
Aporcelaimus sp.	7.6					
	1.0					
Basiria sp.				25.5		
				3.2		
Basiria duplexa				8.5		
Hagemeyer & Allen, 1952				*1.0*		
Cephalobus sp.		5.5	17.8			
		0.8	*5.2*			
C. nanus	7.6	44.2	8.5		4.2	
de Man, 1880	*1.0*	*6.5*	*2.5*		*0.7*	
C. persegnis	15.3					
Bastian, 1865	*2.0*					
Ceratoplectus sp.					8.5	
					1.3	
Cervidellus serratus				8.5		
Thorne, 1925				*1.0*		
C. vexiliger				8.5		
de Man, 1880, Thorne, 1937				*1.0*		
Chiloplacus propinquus	15.3					
de Man, 1921	*2.0*					
Clarcus papillatus				8.5		
Bastian, 1865				*1.0*		
Costlenchus sp.		77.4				
		11.3				
Diphterophora sp.	17.4	5.5				
	2.3	*0.8*				

Table 1. – (continued).

Taxa	1989			1990		
	Variants					
	V0	V1	V2	V0	V1	V2
Diphterophora kirjanovae	8.5					
Ivanova, 1958	*1.1*					
Diplogaster sp.		5.9				
		0.9				
Diplogastrellus cosobrinus		5.5	30.6			31.9
de Man, 1920		*0.8*	*8.9*			*8.3*
Discolaimus sp.	7.6					
	1.0					
Ditylenchus sp.				8.5		
				1.0		
Dorylaimellus sp.	22.9			8.5		
	3.0			*1.0*		
D. stagnalis	15.3			8.5		
Dujardin, 1854	*2.0*			*1.0*		
Eucephalobus mucronatus				25.5	4.2	
Kozłow. & Roguska-Wasilew., 1963				*3.2*	*0.7*	
Eudorylaimus sp.	22.9	5.5		25.5	8.5	
	3.0	*0.8*		*3.2*	*1.3*	
Eumonhystera sp.	8.5		5.5			
	1.1		*1.6*			
E. similis					4.2	
Bütschlii, 1873					*0.7*	
Filenchus sp.	5.9	42.5	2.5	6.0	17.0	
	0.8	*6.2*	*0.8*	*0.7*	*2.6*	
F. discrepans					8.5	
Andrássy, 1954					*1.3*	
F. filiformis	3.8			2.5	17.0	
Bütschli, 1873	*0.5*			*0.3*	*2.6*	
F. misellus		22.1				
Andrássy, 1958		*3.2*				
Hemicyclophora sp.	15.2					
	2.0					
Labronema sp.		27.6				
		4.0				
Macropostonia xenoplax	7.6		2.5			
Luc & Raski, 1981	*1.0*		*0.7*			
Malenchus madachoi				8.5		
Andrássy, 1963, Andrássy, 1968				*1.0*		
Meloidogyne sp.	38.2	11.0	2.5			
	5.0	*1.6*	*0.7*			
Mesorhabditis sp.	15.3			8.5		
	2.0			*1.0*		
Monhystrella paramacrura			2.5			
Meyl, 1953, Andrássy, 1958			*0.8*			
Mononchus sp.	38.3			8.5		
	5.1			*1.0*		
Mylonchulus sp.	38.3	11.0		8.5		
	5.1	*1.6*		*1.0*		
M. micrurus	7.6					
(Cobb, 1917), Andrássy, 1958	*1.0*					
Neopsilenchus sp.				17.0		
				2.1		
Nothotylenchus affinis					8.5	
Thorne, 1941					*1.3*	
Panagrolaimus sp.				8.5		
				1.0		
Panagrolaimus rigidus	15.3		2.5	8.5	8.5	
Schneider, 1866, Thorne, 1937	*2.0*		*0.8*	*1.0*	*1.3*	
Paraphelenchus basili				8.5		
Das, 1960				*1.0*		

Table 1. – (continued).

Taxa	1989		Variants		1990	
	V0	V1	V2	V0	V1	V2
Paratrophurus loofi				25.5		
Arias, 1970				*3.2*		
Paratylenchus sp.	9.4	148.4	86.8	42.5	157.4	
	1.2	*21.7*	*25.3*	*5.2*	*24.4*	
P. bucoviensis		11.0				25.5
Micoletzky, 1922		*1.6*				*6.6*
P. microdorus	5.9	11.0		8.5		
Andrássy, 1959	*0.8*	*1.6*		*1.0*		
P. nanus	11.9		5.1	25.5		
Cobb, 1923	*1.6*		*1.5*	*3.2*		
Plectus sp.	15.3	5.5		17.0	38.2	2.1
	2.0	*0.8*		*2.1*	*5.9*	*0.5*
P. longicaudatus					4.2	
Bütschlii, 1873					*0.7*	
Pratylenchus sp.	7.9		5.1	35.5	25.5	
	1.0		*1.5*	*4.3*	*3.9*	
P. crenatus	4.3	11.0		8.5	17.0	
Loof, 1960	*0.6*	*1.6*		*1.0*	*2.6*	
P. flakkenis	5.9		2.5	25.5		
Seinhorst, 1968	*0.8*		*0.7*	*3.2*		
Prionchulus sp.	7.6			25.5		
	1.0			*3.2*		
Prismatolaimus sp.		5.5				
		0.8				
P. muscorum				8.5		
Dujardin, 1845				*1.0*		
P. punctatus				8.5		
Cobb, 1917				*1.0*		
Rhabditis sp.	15.3	10.6	45.1	17.0	68.0	
	2.0	*1.6*	*13.1*	*2.1*	*10.6*	
Rotylenchus sp.	8.0					
	1.1					
Trichodorus sp.	83.4	27.6	35.7	8.5		
	11.0	*4.0*	*10.4*	*1.0*		
T. cylindricus	5.9	53.1	2.5			
Hooper, 1962	*0.8*	*7.8*	*0.8*			
Tylencholaimus sp.	8.5	5.5				
	1.1	*0.8*				
Tylenchorhynchus sp.	10.4		5.1		17.0	
	1.4		*1.5*		*2.6*	
T. dubius	47.4		5.1	17.0		
Bütschli, 1873, Filipjev, 1936	*6.3*		*1.5*	*2.1*		
T. maximus			11.9			
Allen, 1955			*3.5*			
Tylenchus sp.	3.8			59.5	8.5	
	0.5			*7.3*	*1.3*	
T. davainei	3.8	49.8		17.0	25.5	2.5
Bastian, 1865	*0.5*	*7.3*		*2.1*	*3.9*	*0.7*
T. elegans		5.5				
de Man, 1876		*0.8*				
T. sandneri	3.8			17.0		
Wasilewska, 1965	*0.5*			*2.1*		
Total number	755.9	685.2	343.4	807.6	645.1	385.4

Table 2. – Taxonomic composition of nematode communities in autumn in the control (V0) and two variants of acidification (V1 and V2). Number of individuals (10^{-3} per m^2) (in normal type). Percentage of taxa in the community (in italics).

Taxa	1988		Variants		1989	
	V0	V1	V2	V0	V1	V2
Acrobeles ciliatus				16.2	51.0	
Linstow, 1977				*3.4*	*5.7*	
Acrobeloides bütschlii		13.7				
de Man, 1880		*0.8*				
A. enoplus		16.6				
Steiner, 1938		*1.0*				
Alaimus sp.	56.6	13.6			57.4	
	4.8	*0.8*			*6.5*	
A. parvus		13.6				
de Man, 1880		*0.8*				
A. primitivus		54.4				
de Man, 1980		*3.3*				
Aphelenchoides sp.	7.0	27.2	159.6	44.2		17.0
	0.6	*1.6*	*12.4*	*9.2*		*2.8*
A. composticola						4.2
Franklin, 1957						*0.7*
A. saprophilus	7.0			56.2		21.3
Franklin, 1957	*0.6*			*11.8*		*3.6*
Aphelenchus avenae	14.0	95.3		19.6	19.1	4.2
Bastian, 1865	*1.2*	*5.7*		*4.2*	*4.7*	*0.7*
Basiria magnidens	14.0			4.2		
Thorne, 1949, Geraert, 1968	*1.2*			*0.9*		
B. tumida	14.0					
Colbran, 1960, Geraert, 1968	*1.2*					
Cephalobus nanus	99.1	245.1	117.0	23.8	89.4	25.5
de Man, 1880	*8.4*	*14.7*	*9.1*	*4.9*	*10.1*	*4.3*
Cervidellus vexiliger					6.4	
de Man, 1880					*0.7*	
Chiloplacus symetricus	70.6					
Thorne, 1925	*6.0*					
Costlenchus sp.		68.0	10.6		31.9	
		4.1	*0.8*		*3.6*	
C. cancelatus		68.0		4.2		4.2
Cobb, 1925, Siddiqi, 1981		*4.1*		*0.9*		*0.7*
C. lateralis						8.5
Andrássy, 1983						*1.4*
Diphterophora sp.	30.2	13.6			44.6	
	2.5	*0.8*			*5.0*	
D. obsesus		13.6				
Thorne, 1939		*0.8*				
D. perplexans	140.0			4.2	6.4	
Cobb, 1913	*11.8*			*0.9*	*0.7*	
Ditylenchus sp.					6.4	
					0.7	
Dorylaimellus sp.	28.0			8.5	6.4	
	2.3			*1.8*	*0.7*	
D. aequalis	28.5			4.2	25.5	
Cobb, 1918, Thorne, 1930	*2.4*			*0.9*		
D. labiatus				4.2	6.4	
Thorne, 1964				*0.9*	*0.7*	
D. stagnalis	14.0					
Dujardin, 1845	*1.2*					
Eucephalobus mucronatus					6.4	
Kozłowska & Roguska, 1963					*0.7*	
E. striatus	14.0			8.5		
Bastian, 1865	*1.2*			*1.8*		
Eudorylaimus sp.	14.5	95.3		16.1	63.8	
	1.2	*5.7*		*3.3*	*7.2*	
Eumonhystera sp.					6.4	
					0.7	

Table 2. – (continued).

Taxa	1988 V0	1988 V1	1988 V2	1989 V0	1989 V1	1989 V2
Filenchus sp.	14.0				6.4	
	1.2				*0.7*	
F. filiformis		13.6			12.7	
Bütschli, 1873		*0.8*			*1.4*	
Gracilacus sp.				23.8		
				4.9		
Hemicyclophora sp.	28.0				19.1	
	2.3				*2.2*	
Labronema sp.	14.0					
	1.2					
Lelenchus sp.		7.2			6.4	
		0.4			*0.7*	
L. discrepans		14.0				
Andrássy, 1954		*0.8*				
L. leptosoma		40.8				
de Man, 1880		*2.4*				
Longidorus sp.					6.4	
					0.7	
Macrolaimus taurus				17.0		
Thorne, 1937				*3.5*		
Malenchus sp.	28.0			4.2	6.4	
	2.3			*0.9*	*0.7*	
M. madachoi					6.4	
Andrássy, 1963, Andrássy, 1968					*0.7*	
M. sulcus	14.0					
Wu, 1970, Siddiqi, 1979	*1.2*					
Meloidogyne sp.		21.7		4.2	76.6	
		1.3		*0.9*	*8.7*	
Mesorhabditis sp.	30.2			16.2		
	2.5			*3.4*		
Mononchus sp.	14.0					
	1.2					
Mylonchulus sp.	14.0	40.8				
	1.2	*2.4*				
M. subsimilis				4.2		
Cobb, 1917, Andrássy, 1958				*0.9*		
Nygolaimus sp.					25.5	
					2.9	
Paraphelenchus sp.					6.4	
					0.7	
Paratrichodorus pachydermus			10.6		63.8	
Seinhorst, 1954			*0.8*		*7.5*	
P. teres		13.6				
Hooper, 1962		*0.8*				
Paratylenchus sp.	71.2	184.6	404.2	44.2		42.5
	6.0	*11.1*	*31.4*	*9.3*		*7.1*
P. bucoviensis	28.0			32.3	25.5	127.7
Micoletzky, 1922	*2.3*			*6.8*	*2.9*	*21.4*
P. microdorus	14.0			5.8	25.5	217.0
Andrássy, 1959	*1.2*			*1.2*	*2.9*	*36.4*
P. nanus		13.6	42.5			114.8
Cobb, 1923		*0.8*	*3.3*			*19.3*
Plectus	42.6	13.6		32.3	6.4	
	3.6	*0.8*		*6.7*	*0.7*	
P. tenuis sp.	28.0			4.2		
Bastian, 1865	*2.3*			*0.9*		
Pratylenchus sp.	127.7	95.3	10.6	8.5	12.8	
	10.8	*5.7*	*0.8*	*1.8*	*1.4*	
P. crenatus		51.0	53.2			
Loof, 1960		*3.1*	*4.1*			

Table 2. – (continued).

Taxa	1988		Variants		1989	
	V0	V1	V2	V0	V1	V2
P. fallax		68.0		4.2		
Seinhorst, 1968		*4.1*		*0.9*		
P. flakkenis	42.5			4.2		
Seinhorst, 1968	*3.6*			*0.9*		
P. penetrans		42.5				
Cobb, 1917		*2.5*				
Prismatolaimus sp.				4.2		
				0.9		
Protorhabditis sp.				4.2		
				0.9		
Pungentus pungentus					25.5	
Thorne & Schwanger, 1936					*2.9*	
Rhabditis sp.	40.4	27.2	351.0	4.2	6.4	4.2
	3.4	*1.6*	*27.3*	*0.9*	*0.7*	*0.7*
Rotylenchus sp.				4.2		
				0.9		
Teratocephalus sp.					6.4	
					0.7	
Trichodorus sp.	42.5	27.2	42.5	19.6		
	3.6	*1.6*	*3.3*	*4.1*		
T. cylindricus					63.8	
Hooper, 1962					*7.5*	
Tylenchorhynchus sp.	28.0	27.2	10.6	8.5	12.8	
	2.3	*1.6*	*0.8*	*1.8*	*1.4*	
T. dubius	14.0			4.2		
Bütschli, 1873, Filipjev, 1936	*1.2*			*0.9*		
T. maximus			53.2			
Allen, 1955			*4.1*			
Tylenchus sp.		217.8			12.8	4.2
		13.0			*1.4*	*0.7*
T. davainei					8.5	
Bastian, 1985					*1.0*	
T. elegans				4.2	12.8	
de Man, 1876				*0.9*	*1.7*	
T. sandneri				4.2		
Wasilewska, 1965				*0.9*		
Wilsonema auriculatum		13.6	21.3			
Bütschli, 1873, Cobb, 1913		*0.8*	*1.7*			
Total number	1186.0	1651.8	1308.2	483.6	881.8	595.3

communities were in V1 and the least numerous in V0. The differences between total number of nematodes in both years and seasons in three variants were not statistically significant ($p = 0.16$).

Species range and number of genera

The species range of communities is given in *table* 1 and *table* 2. The communities in V2 differed significantly from communities in the two other variants. In both years and seasons in the assemblages in V2 there were no predatory and omnivorous species. The acidification of soil, especially the strong one affected the number of genera forming the communities (*fig.* 2). In the soil treated with sulphuric acid the number of genera was lower than in the control. There was one exception - the sample taken in the autumn 1989 in which the number of genera in V1 (31) was higher than in V0 (28). The difference between number of genera in V0 and V1 was not statistically significant ($p = 0.5$; Mann-Whitney U-test). In contrast to this the difference between number of genera in V1 and V2, as well as that between V0 and V2 were significant ($p = 0.05$).

The obtained data make it difficult to determine species or genera which reacted positively or negatively to acidification because the percentage of most species varied in the three variants (*tables* 1 and 2). However the extremely high percentage of the genus *Paratylenchus* in autumn 1989 and *Aphelenchoides* in spring 1990 allow to suppose that these two genera can develop better than others in soil treated with sulphuric acid.

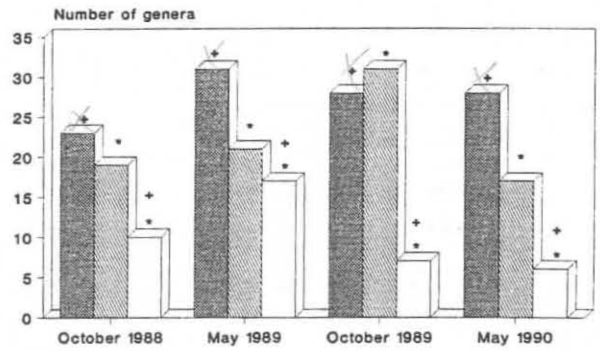

Figure 2. – Number of genera in the nematode communities in three variants. For explanation of the abbreviations *see figure* 1.
* – with p = 0.05 significant difference between V1 and V2 in the same year and season.
\+ – with p = 0.05 significant difference between V0 and V2 in the same year and season.

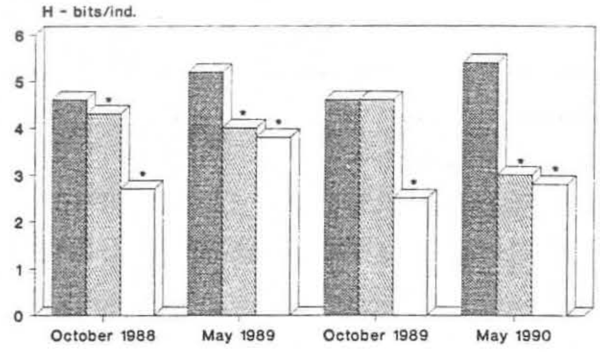

Figure 3. – Values of Shannon diversity index in nematode communities in three variants. For explanation of the abbreviations *see figure* 1.
* – with p = 0.05 significantly different from the control in the same year and season.

Species diversity

The values of H - Shannon diversity index are given in *figure* 3. In both years in autumn and in spring the highest diversity was found in the control. The values of H for these communities ranged from 4.60 to 5.38 bits/ind. In the weak acidification diversity was smaller (3.87-4.65 bits/ind.). The lowest diversity was found in V2, (2.58 to 3.82 bits/ind.). The differences between diversity in control and weak acidification were significant with one exception, in autumn 1989. The differences between diversity in control and strong acidification were significant in both years in autumn and in spring.

DISCUSSION

Sulphuric acid introduced into the soil may affect soil organisms in different ways. It can act directly as a toxic substance or indirectly by changes in chemical properties of the soil, especially of the water phase of the soil. According to Baath *et al.*, (1980) increased soil water acidity will cause increased ion exchange in the soil which in turn causes higher osmotic potential in the soil water. Nematodes as softbodied animals living in contact with water occurring in the soil should be sensitive to changes in the soil water conditions, especially to osmotic potential. The increase of osmotic potential was regarded as possibly factor which limited number of some soil organisms in the soil treated with sulphuric acid (Baath *et al.*, 1980, Ruess and Funke, 1992).

The obtained data indicate that dosages of acid rain applied in this experiment during five years do not significantly affect the total number of nematodes. However, acidification caused some changes in the structure of community. The assemblages in the soil treated with sulphuric acid were poorer in genera than communities in the control. This was clearly visible in strong acidification where communities were composed of only a few species. Such poor communities are abnormal in grass habitats Yeates (1982) studying during 36 months nematode fauna in a pasture found 28 genera. Wasilewska (1974*b*) observed in the pasture 39 genera of nematodes, in meadows 47 genera (Wasilewska, 1976). Nematode communities composed of a few genera only occur in heavily disturbed habitats. For example Kozłwoska (1986) noticed poor communities in a meadow treated with very high dosages of semi-liquid manure. This allows to suppose that dosages of sulphuric acid applied in V2 strongly affected the environment.

High dosages of sulphuric acid lead to total elimination of predatory and omnivorous nematodes. It is difficult to conclude whether the reaction of these two groups was due to the effect of toxity of sulphuric acid or the increase of the soil acidification. However, this confirms the opinion that these two groups are particularly sensitive to disturbances in the environment, such as different kinds of pollution (Zullini, 1976, Zullini and Peretti, 1986), acidity (Burns, 1971; Ruess and Funke, 1992), fertilization (Hyvonen and Huhta, 1989). Therefore, some authors propose omnivorous and predatory nematodes as indicators of ecological changes in the environment (Ferris and Ferris, 1974; Wasilewska, 1974*a*, Zullini, 1976).

The increase of *Aphelenchoides* in strongly acidified soil in spring 1990, confirms the observations made by other authors (Ruess and Funke, 1992; Hyvonen and Persson, 1990) who noticed high density of this genus in the acidified soil. It is possible that the increase of *Aphelenchoides* in this sample was due to the number of fungi which are a food-source of this genus. It is known that the acidity of soil favors the development of some fungi (Baath *et al.*, 1980) (Wainwright, 1979). However, as in this study the number of fungi in the soil samples was not estimated, the above interpretation should rest as a supposition.

The distinct domination of *Paratylenchus* in autumn 1989 is not easy to explain. There is no information concerning the influence of acidification on this genus. However, many plant parasites and so probably *Paratylenchus* too, develop better in slightly acid environment than in alkaline one (Burns, 1971, Kuiper and de Leuw, 1963, Hyvonen and Huhta, 1989).

Wasilewska (1979) analyzing 31 sites compared the diversity index of nematode genera in three ecosystems: grassland, forest and crop-field. Nematode communities in grassland ecosystems showed a higher diversity than in forest or crop-field. The values of Shannon diversity index obtained in this study in the communities from control plots (4.6-5.4 bits/ind.) and from weakly acidified plots (3.8-4.6 bits/ind.) are similar to the diversity index reported by Wasilewska (1979) for communities in grassland (4.0-5.4 bits/ind.). In contrast to this, species diversity in strong acidification significantly dropped, in some samples even below 3. This means that species diversity in strong acidification was smaller than diversity in dry pine forest or potato field which was determined as the least favorable for diversity of nematodes (Wasilewska, 1979).

CONCLUSIONS

The obtained data indicate that dosages of sulphuric acid applied in this study as artificial acid rain during five years caused a decrease of soil pH. The acidification of soil did not significantly affect the total number of nematodes. However, it caused some changes in community structure. In soil treated with artificial acid rain the number of genera and species diversity significantly decreased. Sulphuric acid introduced into the soil eliminated predatory and omnivorous representatives from nematode communities.

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